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Photometric and spectroscopic observations of three rapidly rotating late-type stars: EY Dra, V374 Peg and GSC 02038-00293 ⋆

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Here, $BV(RI)_C$ broad band photometry and intermediate resolution spectroscopy in Hα region are presented for two rapidly rotating late-type stars: EY Dra and V374 Peg. For a third rapid rotator, GSC 02038-00293, intermediate resolution Hα spectroscopy and low resolution spectroscopy are used for spectral classification and stellar parameter investigation of this poorly known object. The low resolution spectrum of GSC 02038-00293 clearly indicates that it is a K-type star. Its intermediate resolution spectrum can be best fitted with a model with $T_{\rm eff}$=4750 K and $v\ \sin i$=90 $\rm km\,s^{-1}$, indicating a very rapidly rotating mid-K star. The Hα line strength is variable, indicating changing chromospheric emission on GSC 02038-00293. In the case of EY Dra and V374 Peg, the stellar activity in the photosphere is investigated from the photometric observations, and in the chromosphere from the Hα line. The enhanced chromospheric emission in EY Dra correlates well with the location of the photospheric active regions, indicating that these features are spatially collocated. Hints of this behaviour are also seen in V374 Peg, but it cannot be confirmed from the current data. The photospheric activity patterns in EY Dra are stable during one observing run lasting several nights, whereas in V374 Peg large night-to-night variations are seen. Two large flares, one in the Hα observations and one from the broadband photometry, and twelve smaller ones were detected in V374 Peg during the observations spanning nine nights. The energy of the photometrically detected largest flare is estimated to be $4.25\times10^{31} - 4.3\times10^{32}$ ergs, depending on the waveband. Comparing the activity patterns in these two stars, which are just below and above the mass limit of full convection, is crucial for understanding dynamo operation in stars with different internal structures.

1 Introduction

Among low-mass stars, the limit of full convection plays an important role. On the two sides of this limit stars are thought to host different kind of dynamos: according to theories, stars above ~0.35 $M_\odot$ have radiative core and a convective envelope (Chabrier & Baraffe 1997), and create their magnetic field with an $\alpha\Omega$-dynamo (e.g., Parker 1955; Babcock 1961; Leighton 1969), similarly to the Sun. Stars below this limit are fully convective, and are found to be rotating almost as rigid bodies (Barnes et al. 2005).

Theoretical studies of Küker & Rüdiger (2005) and Chabrier & Küker (2006) show, that fully convective stars rotating as solid bodies can produce large-scale, non-axisymmetric fields using α^2-dynamo. But Dobler, Stix & Brandenburg (2006) suggest that, these stars can develop axisymmetric poloidal magnetic fields, given that they have strong differential rotation. Regardless of their interior structure, both types show signs of activity (see, e.g., Delfosse et al. 1998).

In this paper we present observations of three rapidly rotating stars: EY Dra, V374 Peg and GSC 02038-00293. It is especially intriguing to compare the observations of fully convective V374 Peg and EY Dra which has a small radiative core.

V374 Peg (RA 22 01 13.11, dec +28 18 24.9, V=11.89 mag) is a fully convective M4 dwarf with a mass of 0.28 $M_\odot$ (Delfosse et al. 2000), whose observed properties can question the existing dynamo theories. The unusual activity of the star has been observed by Greimel & Robb (1998) and Batyrshinova & Ibragimov (2001), who reported frequent and intense flares on the object. Using spectropolarimetric methods Donati et al. (2006) and Morin et al. (2008a) showed that V374 Peg is rotating almost as a rigid body, but at the same time has a stable, axisymmetric poloidal magnetic field contradicting the theoretical models.

EY Dra (RA 18 16 16.05, dec +54 10 16.0, V=11.83 mag) is a well-studied rapidly rotating dM1-2e star (Jeffries, James, & Bromage 1994). Its mass, ~0.49 $M_\odot$ (ac-

⋆ Based on observations made with the Nordic Optical Telescope, La Palma, Spain; Isaac Newton Telescope of the Isaac Newton Group of Telescopes, La Palma, Spain; 60-cm and 1-m telescopes of Konkoly Observatory, Hungary

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cording to Eibe 1998), implies that the star probably has a radiative core and convective outer envelope. Eibe (1998) published Hα observations, and explained them with plages and co-rotating prominence clouds above the surface. Using Doppler images, Barnes & Collier Cameron (2001) showed that EY Dra has spots at all latitudes. They also detected differential rotation with a shear of $\Delta\Omega = 0.0608$, assuming a solar-type differential rotation: $\Omega(\theta) = \Omega_0 - \Delta\Omega \sin^2(\theta)$. Korhonen et al. (2007) presented photometric observations in V and R filters, together with optical and near-infrared spectroscopy, and showed a possible association of photospheric starspots and chromospheric plages. Vida (2007) and Vida et al. (2010) showed evidence for spot evolution on the stellar surface using ∼1000-day-long photometric data, and an activity cycle with a period of ∼350 days. Signs of a possible flip-flop mechanism is also found, which might give indication of the type of the underlying dynamo mechanism producing the observed stellar activity (see, e.g., Elstner & Korhonen 2005).

GSC 02038-00293 (RA 16 02 48.229, dec +25 20 38.20, V=10.62 mag) is a very little studied star that was originally discovered during a programme identifying optical counter parts of ROSAT X-ray sources by Bernhard & Frank (2006). In the same paper photometric observations for 2005–2006 were presented together with older ROTSE data. According to these observations GSC 02038-00293 is an eclipsing RS CVn type binary with the orbital period of 0.495410 days. This value is similar to the one given by the SuperWASP observations (Norton et al. 2007), and is confirmed by the 2007 data (Frank & Bernhard 2007). These investigations also show that the starspot locations are stable over long time periods, but that the exact shape of the light-curve changes on a time scale of weeks. Also, hints of a 6–8 year long activity cycle are seen (Bernhard & Frank 2006). The spectral type of GSC 02038-00293 is determined to be K from low resolution spectra (Dragomir, Roy & Rutledge 2007).

In this paper spectroscopic and photometric observations of these three stars are presented. For GSC 02038-00293 the low and intermediate resolution spectra are used to study the stellar parameters of this poorly known system. For EY Dra and V374 Peg the photospheric activity patterns are deduced from broadband photometry and the chromospheric activity is studied using intermediate resolution observations of Hα line. The activity seen at these different levels of the stellar atmosphere is correlated, and the activity patterns in fully convective V374 Peg and EY Dra, which still has a small radiative core, are compared.

2 Observations

Medium resolution spectroscopy in the Hα region was obtained at the 2.6-m Nordic Optical Telescope (NOT) using Andalucia Faint Object Spectrograph and Camera (ALFOSC) and the Intermediate Dispersion Spectrograph (IDS) at the 2.5-m Isaac Newton Telescope (INT) of the Isaac Newton Group of Telescopes. Both the telescopes are located in the Observatorio del Roque de los Muchachos of the Instituto de Astrofisica de Canarias, on La Palma, Spain. Broadband photometry of EY Dra and V374 Peg was obtained with the 1-m RCC telescope in Piszkéstető mountain station of the Hungarian Konkoly Observatory and the 0.6-m telescope of the Konkoly Observatory at Svábhegy, Budapest. All the observations of EY Dra were phased using the ephemeris:

$$HJD = 2453588.16582 + 0\overset{\mathrm{d}}{.}4587 \times E \qquad (1)$$

(used by Vida et al. 2010), the V374 Peg observations with

$$HJD = 2453601.78613 + 0\overset{\mathrm{d}}{.}4456 \times E \qquad (2)$$

(from Morin et al. 2008a), and the GSC 02038-00293 data using

$$HJD = 2453560.491 + 0\overset{\mathrm{d}}{.}495410 \times E \qquad (3)$$

(from Bernhard & Frank 2006; Frank & Bernhard 2007).

2.1 Spectroscopy

The ALFOSC observations of EY Dra and V374 Peg were obtained using grism#17, and a 0.5 arcsec slit during the nights starting 2008 June 24 and June 28. With this instrument configuration a resolving power $\lambda/\Delta\lambda$ of 10,000 and the wavelength coverage of 6335–6860 Å is obtained. The detector which is an E2V Technologies 2k back-illuminated CCD with 13.5μm pixels shows a strong fringing pattern in the spectrum, which is visible redwards of ∼6400 Å. To remove the fringing pattern, observations were made in sets of five exposures with moving the target along the slit between consecutive exposures. After every five object exposures, a Halogen flat field and a Neon arc spectrum were obtained. In the analysis only the combined spectra are used.

During the night starting 2008 June 24, observations of GSC 02038-00293 were also obtained with ALFOSC using the same setup and observing strategy as for EY Dra and V374 Peg, and during the night starting 2008 June 28 using grism#4 and a 1.3 arcsec slit. The latter instrument configuration gives spectral coverage 3200–9100 Å and a resolving power of ∼700, but with a fringing pattern that gets progressively worse redwards of 6700 Å. Observations of the spectrophotometric standard HD 338808 were also obtained with the same instrument settings. A detailed observing log for the intermediate resolution observations of GSC 02038-0029 is given in Table 1.

The IDS on INT was only used to observe EY Dra and V374 Peg during the night starting 2008 June 26. Grating H1800V centred at 6600 Å was used together with a slit width of 1.4 arcsec, this combination gives spectral coverage of 6280–6962 Å and resolving power of 10,000.

All the observations were reduced using Image Reduction and Analysis Facility (IRAF) which is distributed by KPNO/NOAO.

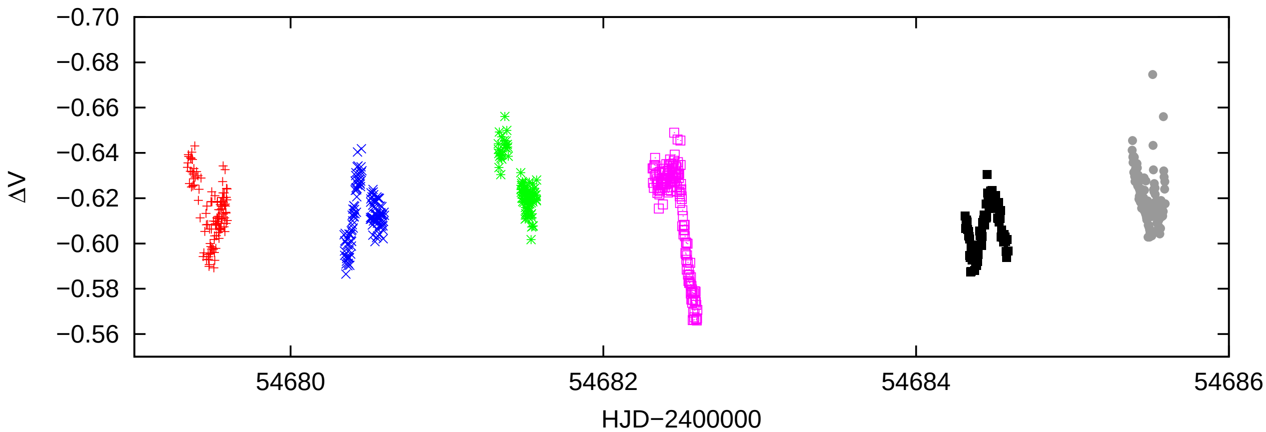

Fig. 2 The V374 Peg V magnitudes plotted against Julian date.

Table 1 Details of the intermediate resolution spectroscopic observations of GSC 02038-00293 obtained on the night starting 2008 June 24. The UT time at the mid point of the observations, heliocentric Julian date, rotational phase using Eq. 3, and the number of observations combined together for each phase. The exposure time for each individual observation is 20 seconds, thus giving total exposure time for each phase of 100 or 80 seconds.

UT midpoint	HJD 2454600+	phase	No of spectra
21:51:58	42.409550	0.8852	5
22:18:16	42.427811	0.9220	5
22:42:29	42.444633	0.9560	5
23:39:42	42.484361	0.0362	5
23:52:01	42.492924	0.0535	4

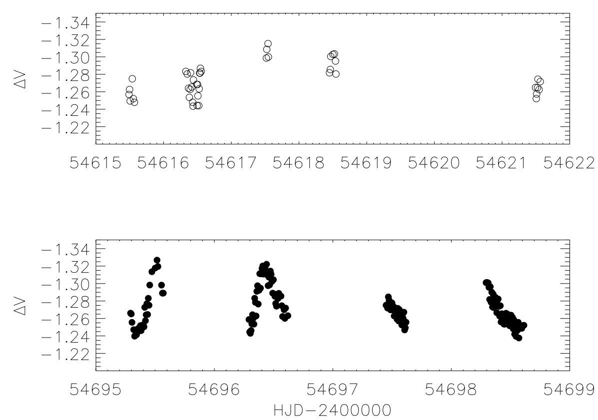

Fig. 1 The EY Dra V magnitudes plotted against Julian date.

2.2 Photometry

In addition to the spectroscopy photometric observations in B, V, R_C and I_C-bands are presented for EY Dra (published also in Vida et al. 2010) and V374 Peg. The photometry of EY Dra was obtained with the 0.6-m telescope. The telescope is equipped with a Wright Instruments 750×1100 CCD. The V-band instrumental magnitudes plotted against Julian date in Fig. 1 show measurements from two observing runs before and after the spectroscopic observations: five nights between JDs 2454615–2454622 (2008 May 29–June 3) and four between JDs 2454695–2454699 (2008 August 16–20). For observing V374 Peg the 1-m RCC telescope with a Princeton 1300×1300 CCD was used. The light-curve in Fig. 2 was obtained from observations taken over six nights between JDs 2454679–2454686 (2008 July 21–August 7).

3 Results

3.1 Photospheric spots from the broad band photometry

As is seen in the Fig. 1, the photometry of EY Dra shows clear variability. If these observations are phased using the ephemeris given in Eq. 1 a broad minimum around phases 0.4–0.9 is seen (Fig. 3, left panel).

To investigate the longitudinal spot[1] configuation in detail light-curve inversion techniques (see, e.g., Oláh et al. 2006) were used to produce a map of the stellar surface showing the fraction of each pixel covered by spots. This so-called spot-filling factor map shows a detailed longitudinal spot distribution, and in some cases, reveals the existence of close-by spots that would not otherwise be separable (Savanov & Strassmeier 2008). But due to the one

[1] Note that throughout the paper term spot does not strictly mean one sunspot-like structure, but can also be an active region consisting of several individual spots. There is no way to distinguish between these cases from light-curves

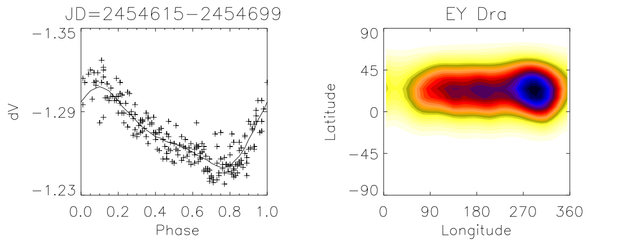

Fig. 3 Phased light-curve of EY Dra. Left: V magnitudes plotted against the phase. Right: spot-filling factor map from the light-curve inversion. Darker colour indicates a larger filling-factor value.

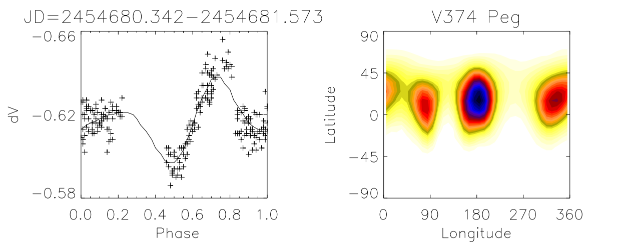

Fig. 4 The same as Fig. 3, but now for V374 Peg. Due to the fast variability in the light-curve only data from two nights have been used (nights starting 2008 August 1 and August 2).

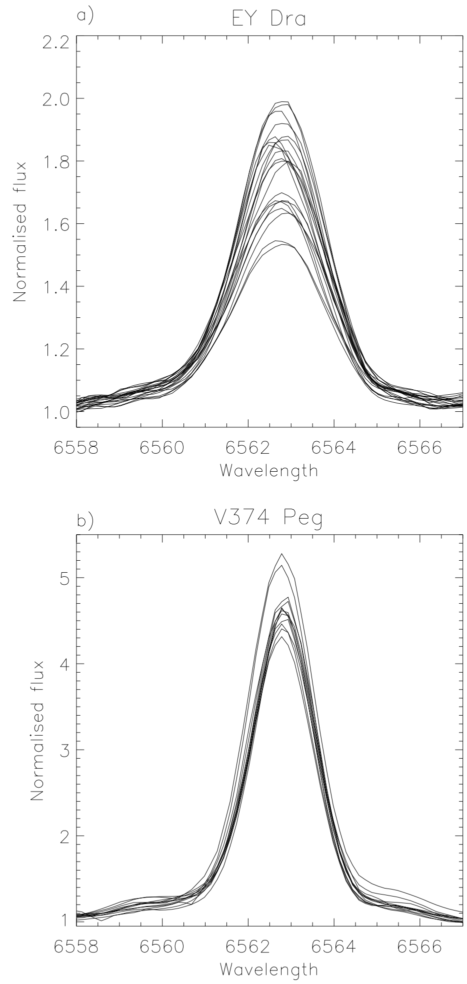

Fig. 5 The Hα line profiles. a) All the Hα lines of EY Dra plotted into the same figure to show the changes in the strength of the line. b) The same as a) but for V374 Peg. Note that the flux scales are different.

dimensional nature of the light-curve, no latitudinal spot information can be obtained from these maps. The resulting spot-filling factor map for EY Dra can be seen in the right panel of Fig. 3. The following parameters were used in the inversion: inclination 66° (Robb & Cardinal 1995), unspotted surface temperature 4000 K (adopted from 3900 K determined by Barnes & Collier Cameron 2001), temperature of spots 3000 K (based on the typical difference between the spot and unspotted surface temperatures in active stars) and limb-darkening coefficient of 0.81 (Al-Naimyi 1978). The map shows primary spot at phase 0.8 (longitude 290°) and an extended secondary spot structure concentrated on phase 0.48 (longitude 170°). This result is similar to the one shown in Korhonen et al. (2007) and Vida et al. (2010). In both cases two active regions on the surface were seen with separation of 0.3–0.5 in phase (110–180°).

The V-band light-curve of V374 Peg for two consecutive nights is presented in the left panel of Fig. 4. The data were phased using ephemeris from Eq. 2. The light-curve minimum occurs at phases 0.3–0.6 (longitude 110–215°). The exact shape of the minimum changes rapidly from night-to-night (also see discussion in Section 4.2). Due to this fast variability, and incomplete phase coverage during a single night, spot-filling factor map for V374 Peg is only obtained from observations spanning two consecutive nights during which the behaviour of the light-curve is similar and stable (JD 2454680.342–2454681.573). Unfortunately this still leaves a gap of 0.2 in phase centred around the phase 0.3 (longitude 110°). The parameters adopted for the light-curve inversion are the same as for EY Dra, except the inclination which is 70° (Donati et al. 2006). Due to the relatively large gap the solution of the light-curve inversion is not stable around these phases. But even then, it is clear from the spot-filling factor map presented in the right panel of Fig. 4, that the spots on V374 Peg concentrate at the phase range 0.9–0.6 (longitude 320–215°), and that the main spot is centred at phase 0.50 (longitude 180°). A secondary spot is also clearly seen centred at phase 0.94 (longitude 340°), but the shape and extent of the other secondary spot seen centred at phase 0.21 (longitude 75°) cannot be determined accurately due to the missing data. It is also plausible that the two secondary spots form one large active region, and not two separate ones.

3.2 Hα line variability

In EY Dra the Hα line is an emission line that shows clear variability, as is also shown in the Fig. 5. The earlier studies

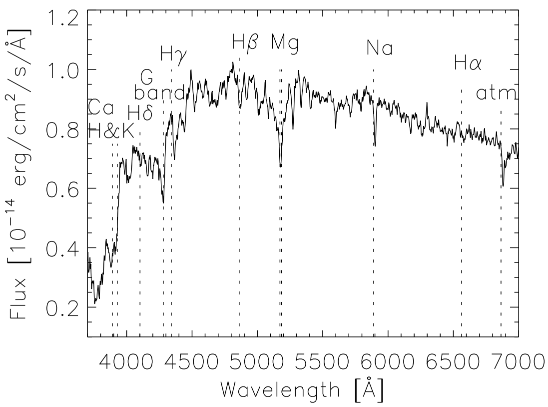

Fig. 6 The low resolution spectrum of GSC 02038-00293 in flux scale. The main spectral features have been identified.

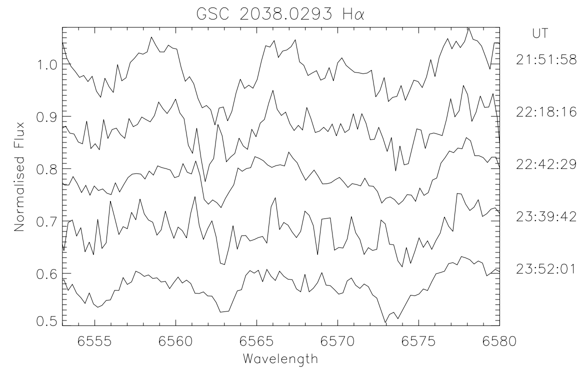

Fig. 8 The five separate exposures of GSC 02038-00293 in the Hα region, from the night starting 2008 June 24. The mid point of the observations are given on the right side of the plot. The spectra are offset from each other by 0.1 in normalised flux.

have shown prominences and cool clouds in the chromosphere (see, e.g., Eibe 1998). Also, in V374 Peg the Hα line is in emission and variable, as shown in the right panel of Fig. 5. The Hα variability is investigated in detail in Section 4.2 and compared to the behaviour of the photospheric spots.

3.3 GSC 02038-00293

The low resolution spectrum of GSC 02038-00293 which is shown in Fig. 6 was used for spectral classification of this target. The main spectral features seen are neutral metals, like Mg and Na. Weak Balmer lines are also present, but no clear molecular bands are detected. All these features indicate a K-type star, as was also deduced by Dragomir, Roy & Rutledge (2007) from earlier low resolution spectra.

The intermediate resolution spectrum of GSC 02038-00293 in the Hα region, after combining the five individual observations, is shown in Fig. 7a. As can be seen, the spectral lines are very broad and Hα itself is a very weak absorption line. Synthetic stellar spectra were calculated using SPECTRUM code (Gray & Corbally 1994) and Kurucz model atmospheres (Kurucz 1993). For the calculations $\log g = 4.5$ was adopted. The best fit to the observed spectrum was obtained for $T_{\rm eff} = 4750 \pm 250$ K, microturbulence velocity $\xi = 1.5\,{\rm km\,s^{-1}}$, and $v \sin i = 90 \pm 10\,{\rm km\,s^{-1}}$(see Fig. 7b). Due to the low resolution and poor signal-to-noise ratio, the errors in these parameters are quite large. Using the $v \sin i$ measured in this work and the rotation period of 0.495410 days (Bernhard & Frank 2006), the estimated radius of GSC 02038-00293 is $\mathrm{R} \times \sin i = 0.88 \pm 0.10 \mathrm{R}_\odot$, implying spectral type of late-G or later.

The comparison of the averaged Hα line spectrum to the model shows that this line in GSC 02038-00293 is clearly weaker than expected at this temperature and $\log g$. This could be explained by magnetic activity in which the chromospheric activity is partly filling in the line core. The five individual exposures of the GSC 02038-00293 Hα region show clear time variability, as seen from Fig. 8. The first exposure shows clear and strong absorption line. With time, the line gets progressively shallower, thus explaining the weak Hα line seen when combining all the observations to a better signal-to-noise spectrum (shown in Fig. 7). This implies variable chromospheric emission in GSC 02038-00293. The hypothesis is further strengthened by the reported prominent Ca H&K emission cores observed in GSC 02038-00293 (Dragomir, Roy & Rutledge 2007)

It is worth noting that the line-profiles of GSC 02038-00293 are slightly triangular. This could imply a secondary component in this system which may affect the spectral line profiles. Since this system is thought to be a RS CVn-type binary (Bernhard & Frank 2006; Frank & Bernhard 2007; Eker et al. 2008), it is not unlikely that there is a spectroscopically detectable companion. But, observations at other epochs are needed to confirm this hypothesis. Also, if the system is a spectroscopic binary, and the secondary during these observations was in such an orbital phase that its spectral lines are superimposed with the primary lines, the stellar parameters determined here (effective temperature and $\mathrm{v}\sin i$) would also be affected by the secondary.

4 Discussion

4.1 Flares

On JD2454685 (2008 August 6) an energetic flare was observed on V374 Peg (see Fig. 9). This event lasted ~1 hour, and could be observed in all the filters, $BV(RI)_C$. The peak of the flare happened after a B exposure, so in this filter only the declining phase was detected. For estimating the energy of the flare the method described by Kővári et al. (2007) was applied. Instrumental magnitudes were used for calculations, since the interpolation needed for transforming to the international system would blur the fast changes in the light-curve. The resulting energies are 2.04×10^{32},

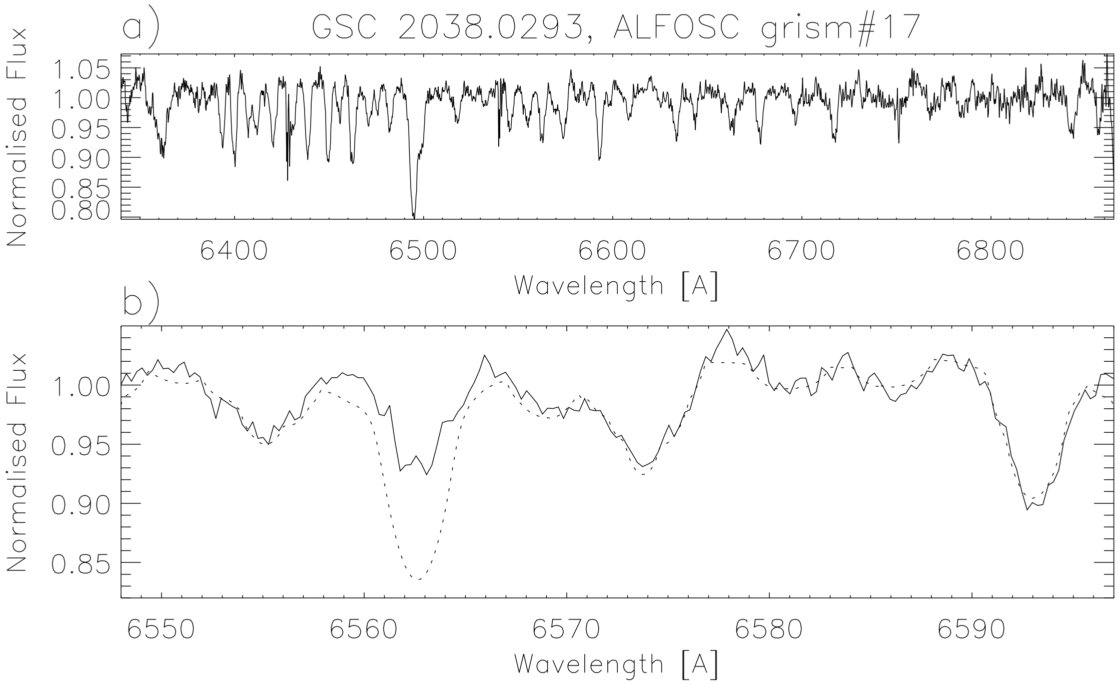

Fig. 7 The intermediate resolution spectrum of GSC 02038-00293. a) The whole spectrum obtained with grism#17. b) Smaller region of the same spectrum (solid line) together with a model (dotted line) calculated using $T_{\rm eff}$=4750 K, $\log g$=4.5, microturbulence velocity 1.5 $\rm km\,s^{-1}$, and vsin i=90 $\rm km\,s^{-1}$.

3.00×10^{32}, 4.30×10^{32}, and 4.25×10^{31}ergs in B, V, R_C, and I_C filters, respectively. As can be seen in Fig. 9, additional smaller flares occur before and after this major event.

Another flare in V374 Peg is detected in Hα around phase 0.2 in the observations from the night starting 2008 June 26. This flare can be seen in the equivalent width measurements shown in Fig. 12b. Unfortunately, only the end stages of the flare are recorded. Thus, no information on the strength and the length of the flare can be given.

Besides these two energetic flares, twelve smaller events can be seen in the photometric data on the last three nights. In Fig. 10 the flares in B band light-curves for the last three observing nights are shown. Most flares seem to erupt in the phases 0.9–0.3. The observed Hα flare also occurs at the same phase range. Though, smaller events can happen at all phases. The night-to-night light-curve changes and the continuous flaring are clearly related showing the very active nature of this star.

4.2 Correlating photospheric and chromospheric activity

The photometric observations of EY Dra are not taken at the same time as the spectroscopic ones, but the observations obtained ∼25 days before the spectroscopy show the same light-curve shape as the photometry obtained ∼55 days after the spectroscopic observations. Therefore, the observations from different epochs can be compared.

The phased light-curve of EY Dra is shown in Fig. 11a together with the equivalent widths measured from the Hα line profiles (Fig. 11b), and the phased colour index curves of EY Dra in B-V (Fig. 11c) and V-I (Fig. 11d). The B-V is practically flat except for a small increase at phases 0.1–0.3. Just like the V-band light-curve, V-I curve also indicates two cool spots around 0.4 and 0.8 phases (see Fig. 3).

The comparison clearly shows that at the phases of the photospheric spots, more emission is seen in the chromosphere. This configuration implies that the chromospheric plages on EY Dra concentrate at the locations of photospheric spots, as is also the case for Sun. It is only recently that this behaviour has been observed in several active stars, e.g., RS CVn-type binaries λ And and II Peg (Frasca et al. 2008a), rapidly-rotating K1-dwarf LQ Hya (Frasca et al. 2008b), T Tauri-type star TWA 6 (Skelly et al. 2008) and for a young, late-type star, SAO 51891 (Biazzo et al. 2009).

Also, for V374 Peg the spectroscopic and photometric observations are not contemporaneous, but the spectra have been obtained ∼40 days before the photometric observations. It has been shown elsewhere (e.g., Morin et al. 2008a) that the active regions in V374 Peg do not change quickly. Hence, the photometry and spectroscopy can be compared.

In Fig. 12 the V-band light-curve (Fig. 12a), equivalent widths measured from Hα (Fig. 12b), and the B-V

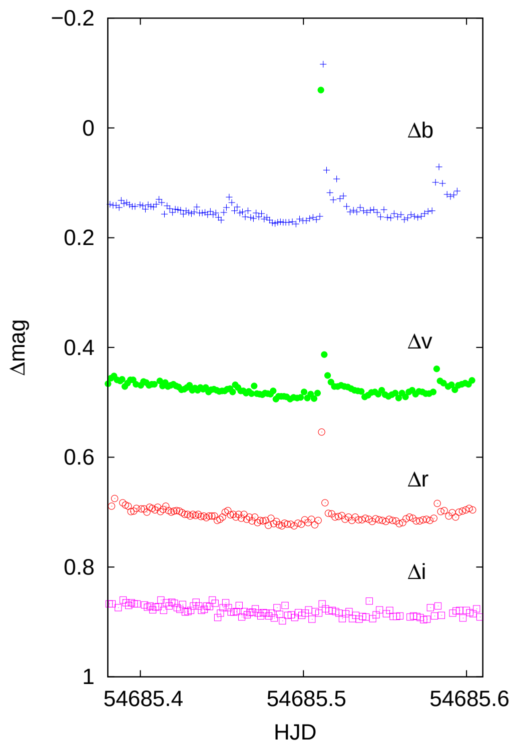

Fig. 9 Flares seen in V374 Peg from the photometric observations of the night starting 2008 August 6. The light-curves have been shifted arbitrarily. The light-curves show instrumental values (see text).

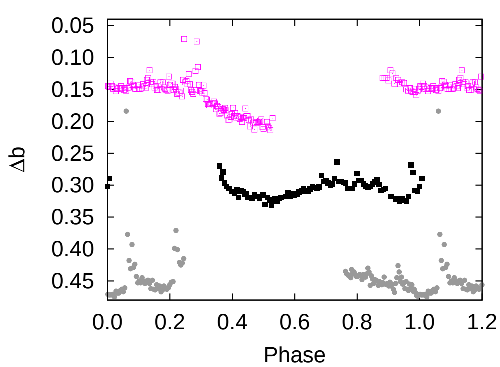

Fig. 10 The phased B light-curves from Julian dates 2454682–2454685. The light-curves from different nights have been shifted, to show better the behaviour. Twelve small flares are seen in these data around phases 0.9–0.3. The plot shows light-curves with instrumental magnitudes.

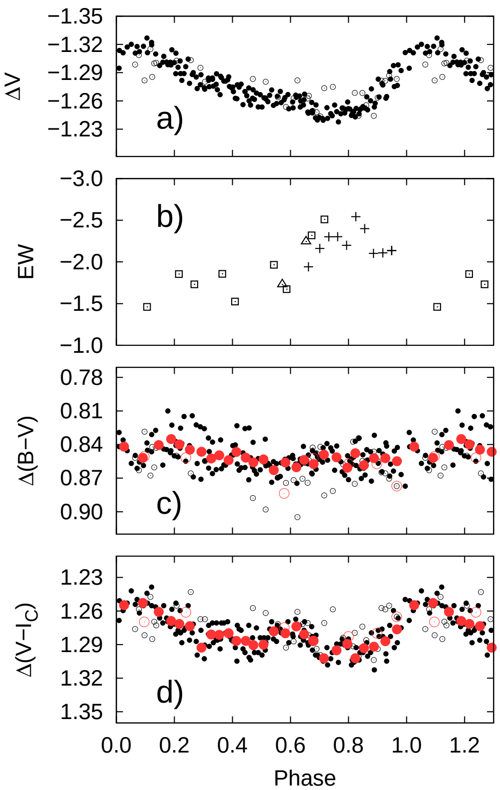

Fig. 11 The comparison of the photospheric and chromospheric activity in EY Dra. a) The V magnitudes plotted against the rotational phase. Filled and empty circles show observations from different epochs (see Fig. 1.) b) The Hα equivalent widths plotted against rotational phase. Different symbols denote observations from different nights. Triangles and boxes show NOT observations from June 24 and June 28, respectively, crosses mark the INT data from June 26. c) The B-V colours plotted against the phase. The larger symbols are an average of typically five individual observations obtained close in time. d) Same as c) but for V-I.

(Fig. 12c) and V-I (Fig. 12d) colours are shown. The V-band observations are plotted with different symbols for the observations from different nights. Very rapid night-to-night variations are seen in the shape of the minimum around phases 0.3–0.6. Also, changes in the maximum around the phase 0.8 are seen during the observations spanning seven nights. As for EY Dra, the B-V colour of V374 Peg is basically flat and does not show marked variability. Between phases 0.9–0.3 the B-V colour index shows high scatter because of the flares concentrating in this part of the light-curve (see Fig. 10). The V-I on the other hand again clearly shows the locations of the main cool spots in the photosphere around phase 0.5.

The comparison of the chromospheric and photospheric activity in V374 Peg does not show as clear a picture as in the case of EY Dra. As can be seen from Fig. 12 a slight increase in the chromospheric emission is seen at the phases of the photospheric spots. But, this increase is very weak, and the Hα observations do not cover the phases of the main active region, thus making it impossible to draw clear conclusions on the possible correlation.

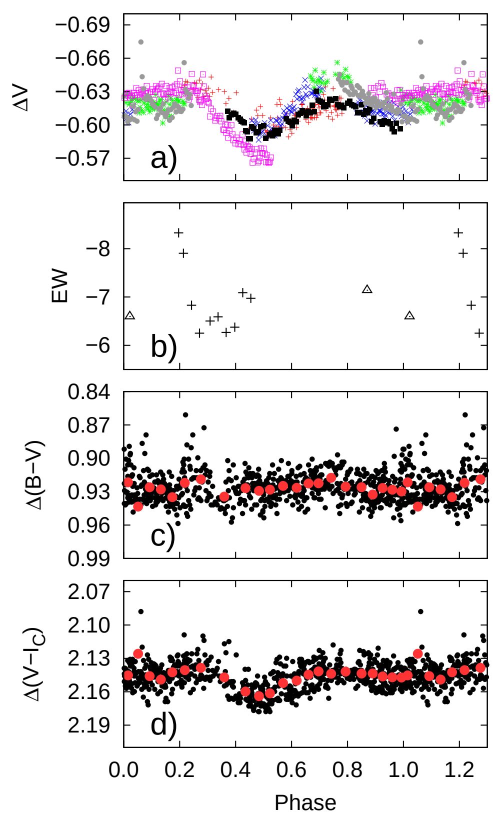

Fig. 12 The same as Fig. 11, but now for V374 Peg. Panel a) show different nights with different symbols and colours (see Fig. 2).

4.3 Comparison of activity patterns in EY Dra and V374 Peg

EY Dra and V374 Peg are both M dwarfs, but on different sides of the mass limit for full convection. EY Dra still has a small radiative core, whereas V374 Peg is fully convective. This change in the interior structure of a star plays an important role in the dynamo operation. Thus, it is very interesting to compare the activity seen in these two stars.

The spot configuration in EY Dra shows two active regions, a configuration that has been reported also in earlier papers (see, e.g., Korhonen et al. 2007; Vida et al. 2010). The light-curve changes on long time scale (a 350 day long activity cycle has been reported by Vida et al. 2010), but is stable from night-to-night throughout more than 80 days (i.e., $>$160 rotations) of our observations (see Fig. 1 and Fig. 3). In V374 Peg the overall activity seems to stay stably at the same location for a long time (Morin et al. 2008a), but the night-to-night variability shown here in the photometric observations from six nights is large. This implies that in V374 Peg fast rearrangement of spots occurs, but the active longitude itself stays at the same location on the stellar surface.

In EY Dra clear correlation between the photospheric spots, and chromospheric emission is seen: enhanced emission occurs at the phase of the spots. In V374 Peg hints of similar correlation are seen, but unfortunately there are not enough chromospheric data from the phases of photospheric spots to confirm this behaviour.

Both of the stars show flaring activity. During the 12 nights of observations presented here no flares were seen in EY Dra, but several were reported in the long-term monitoring by Vida et al. (2010). In V374 Peg the current data obtained during nine nights, shows two large flares: one seen in the photometric observations, and another in the Hα line. In addition, twelve smaller flares are detected in the broadband photometry. This implies that flares in V374 Peg are numerous, and occur more frequently than in EY Dra.

The spectropolarimetric observations of M dwarfs show different magnetic configurations for fully convective and not fully convective stars. Donati et al. (2008) show that early M dwarfs, which still have a small radiative core, show predominantly toroidal and non-axisymmetric poloidal configurations, and have strong surface differential rotation. In the sample of Donati et al. (2008) only the lowest mass early M dwarf showed dominantly axisymmetric poloidal fields, as is seen for the mid-M dwarfs which have masses close to full convection limit (Morin et al. 2008b). Also, the early M dwarfs show long-term variability (Donati et al. 2008) whereas the mid-M dwarfs exhibit stable active region configurations (Morin et al. 2008b). The observations presented here seem to agree with this picture. But the fully convective stars, which do not generally seem to show long-term changes in their spot configurations, can still show fast short-term changes as is seen in V374 Peg. This implies that even if the active region is stable for a long time, the exact spot configuration within the active region itself changes on short time scales.

5 Conclusions

From the broad band photometry and intermediate resolution spectroscopy in the Hα region the following conclusions can be drawn:

- The low resolution spectrum shows that GSC 02038-00293 is a K-type star. The obtained effective temperature of 4750 ± 250 K, based on the intermediate resolution spectra, agree with the mid-K spectral type.
- GSC 02038-00293 has $v\ \sin i = 90 \pm 10\,\mathrm{km\,s^{-1}}$.
- Time variability is observed in the strength of the Hα line in GSC 02038-00293, indicating that this star is chromospherically active.
- Active regions on EY Dra are centred at phases 0.48 and 0.80 in 2008 June–August.
- Photospheric spots in V374 Peg occur at phases 0.3–0.6.
- Very strong night-to-night variation in the exact shape of the light-curve minimum is seen in V374 Peg. This behaviour implies that even if the activity is stably located at certain region of the star the exact spot configuration within the active region changes rapidly.
- Two large flares, one detected in the broadband photometry and one in Hα observations, are seen on V374 Peg

during the nine nights the data presented here cover. In addition twelve smaller flares are seen in the photometric observations.
– The enhanced chromospheric emission in EY Dra occurs at the same phases as the photospheric spots, indicating plages collocated with the starspots, as is also observed in the Sun. V374 Peg also shows some hints of this behaviour but from the data presented here no firm conclusions can be drawn for this issue.

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